DEVELOPMENT OF TANGIBLE TERRAIN REPRESENTATION SYSTEM FOR HIGHWAY ROUTE PLANNING

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ABSTRACT

In recent years, mixed reality, which aims to integrate virtual space with real space have be received a significant amount of attention in research and development. In particular, tangible interface is one of the interesting research growth area. Believing that the introduction of a tangible interface helps recognize the 3-D feature of the terrain, a tangible terrain representation system (TTRS) for highway design is under development by the authors. The TTRS can represent a terrain surface by controlling the shape of a stretchable screen used to represent the terrain surface by means of a total of 64 actuators (8×8) and projecting an aerial photograph onto the screen. Applying the TTRS to highway planning, a highway alignment is determined by control points which are positioned by the magnetic position device. As a highway planner set the control point of a highway alignment on the TTRS, the image of a highway alignment is projected on the TTRS. By using this system, a planner can obtain images of terrain and highways intuitively without wearing any head mounted equipment. The paper outline future development which is required to improve the presentation of precise terrain in the TTRS, and develop its application for design.

KEY WORDS

Virtual reality, Tangible display, Highway Design, Digital Terrain Model, CAD

INTRODUCTION

Current methods of highway alignment planning, in which 2-D topographic maps are used as a base. A planner of the highway must reconstruct a 3-D topographic image from 2-D maps in his/her mind. However accuracy of such images depends on his/her ability and experience. Recent advances in the development and dissemination of spatial information have made it possible to obtain and use various type of spatial information easily. It is also becoming possible to obtain and use topographic information is in many cases which can be provided in the form of mesh data such as USGS Digital Elevation Models (DEM). Such information may be provided bird's eye view prepared by projection translation in two dimensions on a computer display, however, this representation methods make it difficult to understand topographic relief intuitively.

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To solve this problem, the authors have been developing methods for representing virtual terrain surfaces defined on the computer by applying virtual reality (VR) technology and of highway design systems that can be realized by applying those methods, such as the highway route planning system using stereoscopic visualization of aerial photographs, or VR-CAD for landscape design using a head-mounted display. However these systems have some problems, for example, the planner must wear special stereoscopic visualization devices. In recent years, research and development efforts associated with mixed reality, which aims to integrate virtual space and real space have also been developed. One of these efforts is the research and development of tangible interface. Believing that the introduction of a tangible interface helps solve these problems, authors have been working on the construction of a tangible terrain representation system (TTRS) for highway design. This paper introduces an discuss the mechanism of the TTRS and highway planning method using this system.

VR-BASED VISUAL 3D REPRESENTATION METHOD

Virtual reality (VR) is a technology to experience a realistic virtual world defined on the computer. The technology uses an interface which makes an effective use of stereoscopic visualization and this can be made possible by means of the two human eyes in order to visually enhance the degree of reality.

The mechanism by which a human visually recognizes the three-dimensional configuration of an object involves two types factors: physiological factors and psychological factors. Physiological factors, which are due to the functions of the human eye, include the focus adjustment function of the lens, eye convergence, binocular parallax and monocular motion parallax. Psychological factors, which help reconstruct 3D images from experience, are classified either as geometric or optical. Among these factors, binocular parallax, which is one of the physiological factors, is generally thought to be most important in 3D perception.

The stereoscopic visualization technology used in the field of virtual reality is based mainly on 3D perception caused by binocular parallax. If the locations of the eyes of a human viewer are determined in a virtual space de-fined on the computer, a pair of perspective images just like images that would be perceived by the two human eyes can be obtained by applying computer graphics (CG) technology. By giving the perspective images thus obtained to the two eyes of a human viewer, the viewer can be made to perceive the images as a 3D object. Devices for giving different images to the left and right human eyes have been developed during the evolution of virtual reality technology. Representative examples of such devices are stereoscopic eyeglasses with liquid crystal shutters, 3D displays, head-mounted displays (HMD) and immersive displays such as CAVE (e.g., Cruz-Neira, 1993).

In recent years, research efforts associated with mixed reality, which aims to integrate virtual space and real space have also been developed. One of these efforts is the research and development of tangible interface. The MIT Media Laboratory, for example, has developed a system called "Illuminated Clay," which projects information onto a terrain surface created with clay (Piper et.al., 2002).

VR-BASED HIGHWAY DESIGN SYSTEM DEVELOPED TO DATE

The authors have been working to develop terrain representation methods making use of VR technology and construct design support systems using this methods. This paper describes: a road design support system that uses stereoscopic visualization of aerial photographs and a terrain representation and urban space modeling system that uses an HMD, both of which have been developed by the authors, along with problems of these systems.

HIGHWAY ROUTE PLANNING SYSTEM USING AERIAL PHOTOGRAPHS

Makanae(2002) has developed a system (HRPS; Highway Route Planning System) that acquires terrain images through the stereoscopic visualization of aerial photographs and enables road design. Aerial photograph images taken into the computer in the form of digital information are shown on the display of a stereoscopic viewer (CrystalEyes2 manufactured by Stereo Graphics, Inc.) as information that can be visualized stereoscopically. A coordinate system identical to the stereoscopic visualization space obtained by aerial photograph orientation is defined on the computer, and road design is conducted in this 3D virtual space. Parametric curves (B-spline) are used to define road alignments, and control points are located within the space so that their alignments can be defined easily. A 3D model of each road structure is automatically generated according to the alignment defined on the aerial photograph, and plans, longitudinal profiles and perspectives can be displayed.

The main advantage of this system is that it allows an engineer who is might be good at interpreting topographic characteristics (e.g., landslides) from aerial photographs to directly determine road alignments with the assistance of a road de-sign module that uses parametric curves. This is particularly advantageous in, for example, designing mountain roads under poor topographic conditions. By making direct use of aerial photographs, unnecessary mapping processes can be eliminated. A problem with this system is the applicability of road alignments determined by using parametric curves to the current design standard. An-other problem is that the relationship between constructed road structures and the terrain surface represented in a virtual 3D visualization space cannot be computed.

TERRAIN REPRESENTATION METHOD USING HMD: VR-CAD SYSTEM

In the conventional drawing-based space design method, the designer constructs 3D configurations in his or her mind while preparing drawings. VR technology, however, makes it possible to define any 3D virtual space on the computer. The VR-CAD system developed by Makanae (2003) enables the designer to immerse himself or herself into a virtual space constructed on the computer. In the virtual space, the designer can exist on any scale: the designer can enter the space either as a correctly scaled human figure or as a giant. The system also enables the designer to conduct 3D design without relying on the 2D/3D conversion capability of the designer.

The system consists of a head-mounted display (HMD) and 3D position sensors. By combining the HMD and a position sensor, the position and orientation of the head can be measured and appropriate images can be displayed so that the design has a 360-degree field of view both in the horizontal direction and in the vertical direction.

Since the system is intended for use in constructing large structures such as roads, terrain information is essential. Elevation data (50 m mesh) in Digital National Land In-formation are used as 3D terrain models for terrain representation in the virtual space. The modeling input inter-face of the VR-CAD system has a 3D mouse and key-board equipped with a position sensor. These devices enable 3D modeling of such features as buildings (rectangular prisms, cylinders), roads and trees by simple operations. Known problems of the design interface of this system include the difficulty in perceiving the position of the 3D cursor and the difficulty in comprehending the relative positions of the terrain surface and the object of interest.

DEVELOPMENT OF TANGIBLE TERRAIN REPRESENTATION SYSTEM

From the above discussion, problems of the terrain representation and design support systems include the following:

- Difficulty in comprehending the relative positions of the terrain surface and the object of interest
- Need for a special stereoscopic visualization device
- Limited field of view
- Not usable for group work

Believing that the introduction of a tangible interface helps solve these problems, the authors have been working on the construction of a tangible terrain representation system.

Figure 1 shows the configuration of the terrain representation system. As shown, the system represents a terrain surface by controlling the shape of a stretchable screen used to represent the terrain surface by means of a total of 64 actuators (8 by 8) and projecting an aerial photograph onto the screen. The size of screen is 60cm by 60cm square, and the moving range of each actuator is about 250 mm.

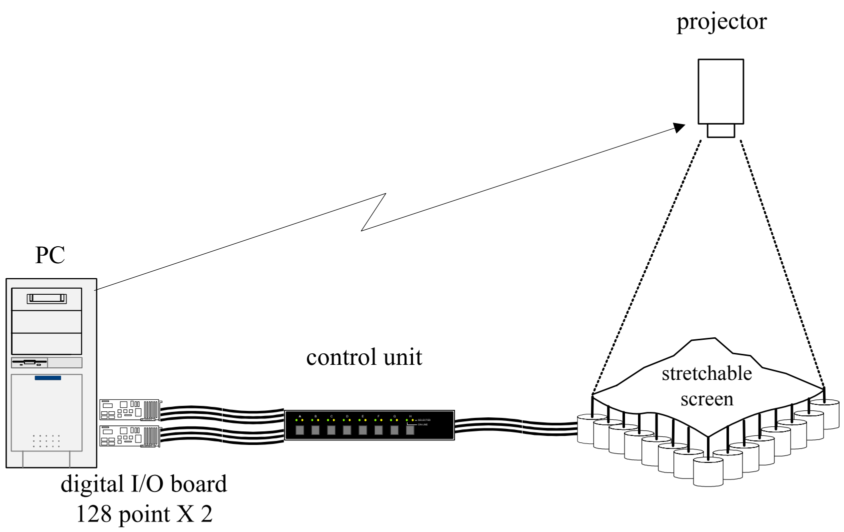

Figure 1: The configuration of the terrain representation system.

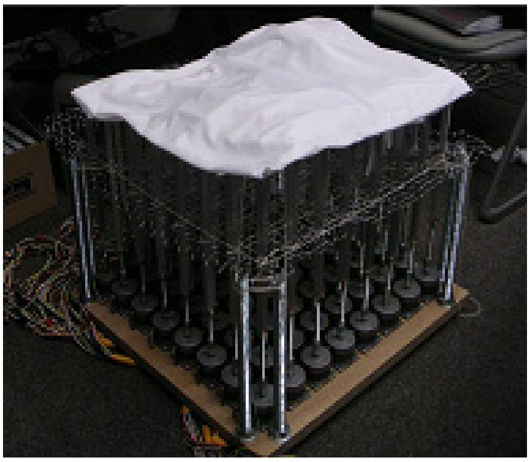

Figure 2: An Overview of the TTRS

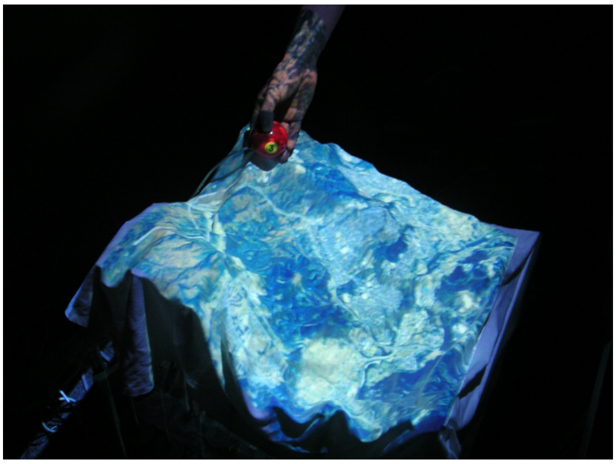

Figure 3: Highway Route Planning Using the TTRS

Mesh data of Digital National Land Information (Japan) are used as terrain data, and the height of each actuator is determined according to the mesh data values.

Figure 2 shows an overview of a terrain represented by using the system. An aerial photograph is projected onto the stretchable screen..

APPLICATION TO HIGHAY ROUTE PLANNING

As a highway alignment is designed as a combination of 2D alignment such as a horizontal alignment or vertical alignment in the conventional method, however, a 3D highway design method is not established. In this study, the 3D parametric curve is applied to the 3D highway alignment. To draw the 3D highway alignment in the 3D virtual space, a highway planner must set some control points for a parametric curve. In this system, the magnetic tracking system POLHEMUS FASTRAK, is used for a pointing device. As the planner set the control point on the TTRS, the parametric alignment can be calculated automatically, and then it is overlaid on the aerial photograph and projected on the TTRS (Figure 3). By using this system, the planner can obtain images of terrain and highways intuitively without wearing any equipment.

CONCLUSIONS

For planning highway routes, planners must consider the harmony between terrains and highways, it is important for planner to imagine the terrain feature of planning area correctly. This paper describes the terrain representation methods and their application which help planners to imagine the terrain feature, and shows the TTRS which can display the terrain physically. The highway design system using the TTRS is now under development; however it helps to understand the feature of terrain intuitively.

Feature development will be focusing an improving the TTRS which can present terrain more precisely, and develop its application for design. Furthermore evaluation of these systems will be carried out.

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REFERENCES

Cruz-Neira,C, Sandin, D.J., Defanti, T.A.(1993). “Surroud-Screen Projection-Based Virtual Reality: The Design and Implementation of the CAVE.” Proceed-ings of SIGGRAPH’93, 135-142.

Makanae, K. (2002). “Stereoscopic Systems for 3-D Highway Route Planning on Aerial Photographs.” International Journal of Design Sciences & Technology, Vol.9-1, 15-22. Europia Productions.

Makanae, K.(2003). “Development of the VR-CAD System for Landscape and Town Planning.” Proceedings of the CONVR2003, Virginia Tech, 114-121.

Piper,B., Ratti,C., Ishii, H. (2002). “Illuminating Clay: A 3-D tangible interface for landscape analysis” Proceedings of the Conference on Human Factors in Computing Systems (CHI’02) 20–25 April, Minneapolis.